panied by strong squally winds, absolutely require storm warnings, but it often happens that these outbreaks fail, due in the cases especially reviewed to just the above-described and partly unexpected formation of a secondary in the awaited cold front.

On the 8 a. m. chart for February 9 (Synoptic charts, Bergen Weather Bureau) a squall-line was lying east of Iceland, with a rising tendency in the pressure in some places of as much as +7 mm. in three hours. A storm warning was issued for the coast from Bergen northward. The expected gale did not come, but on the 2 p. m. chart of the next day a secondary was revealed forming southwest of Lofoten. This secondary gave a southwesterly prefrontal gale for quite another part of the coast.

Secondaries occur in both the southwesterly and westerly types. The series may or may not be marked by them. Perhaps we think they are lacking only because they have not been detected on the chart. The question is certainly open to much discussion and study.

The type termed southerly, or more properly south-southwesterly, is more of a spring or summer phenomenon in contrast to the winter westerlies. The series is marked by long occluded waves, seldom by waves having a well-developed warm sector. They extend from a stationary center to the south of Iceland south over England and France. These waves are probably generated farther south than those of the series mentioned earlier in this discussion. The general trend of the isobars is north-south and the extended valley of relatively low pressure south of Iceland is an effective shelter against the protrusion of cold polar air under warm tropical, until somewhere rather far south of Cape Farewell.

The tropical high in this case generally is pushed eastward until its center lies near Spain and the Mediterranean. The high is accentuated. This is partly due, in all probability, to the descent of the outflow of air in the upper strata from the cyclones to the west of the high. The length of the path of the cold air from this source to its turning point and back toward the British Isles naturally exhausts much of its original potential energy. The temperature difference between polar and tropical air is less marked under these circumstances, and on this account the cyclone is poorly developed in the beginning, and consequently after its journey northward is still feebly developed, which is seen by the dimensions of its warm sector, the boundaries of which then, especially in the more central parts of the cyclone, between Iceland and the British Isles, are clapped together.

Secondaries also occur in the southwesterly type, although of a somewhat different nature than in the westerly type. Apparently every primary wave has secondaries which appear first over England and France as quasi-warm sectors attached to the occluded primary. The origin of these secondaries is in reality not so far different from the origin of the secondaries in the types mentioned above.

The occlusion has the character of a so-called cold front, advancing from the south-southwest although the instability of the cold air over the warm surface is less marked. When the cold front advances against air that is warm enough in comparison with the polar air, a warm or quasi-warm sector is formed in that part of the cold front. This generally is the case over south England and western France. This is also characteristic of the secondaries of the first-mentioned types. Showers follow the passage of the occluded wave, indicating the unstable nature of the air.

Secondary cyclones often originate in a well-developed cold front. This may occur after the third wave, but more especially the fourth of a series, because these sweep so far south that they come up against air warm enough to feed a warm sector. These secondaries may often have a very innocent aspect upon their first appearance on the synoptic chart, but develop into cyclones with gradient and wind field exceeding that of the primary cyclones. This is the case especially in summer, when the general circulation is less accentuated, with the regeneration of old "secluded" cyclones or cold fronts which have been nearly obliterated but may be revived by a renewal of the warm air supply from a warm continent. It may also happen that new fronts are developed in the cold polar air of a recent outbreak, when the air has been sufficiently warmed in parts to give enough contrast in temperatures. Thus, also, new fronts may develop along the coast of a continent in the winter time due to the contrasts in temperature between the cold air masses of an anticyclone cooled by radiation and the relatively warm air over the adjoining sea or ocean. For instance, such a "maritime" front gave the snowstorm of 500 millimeters of precipitation at Bergen in November, 1919. Secondary fronts in summer frequently develop over Denmark and northern Germany, and, moving very slowly following the upper drift, give great amounts of rain in Denmark and southern Sweden. This type of discontinuity is often very intricate and extremely hard to trace on the map, often lacking a marked resemblance to the life forms described above. The pressure field often takes the form of a barometric valley or trough. The slow propagation of these "amoeba" cyclones and the strong convergence of winds make them one of the strongest rain producers in southern Sweden. The same is the case when an originally real polar front is retarded in its movement or becomes stationary.

It may be pointed out that the average duration of each wave in a family according to the statistics of the first 140 days at the beginning of 1921, is 6.5 days for Scandinavia in good accordance with the period of Defant for average precipitation periods found for the Northern Hemisphere. The existence of a periodicity is also known for the Southern Hemisphere. Quite probably further details could be determined from a study of the phenomena of the "southerly burster" of Australia and the "pampero" of Argentina, both typical cold-front phenomena.

The step to tropical cyclone is natural. Professor Bjerknes[16] has advanced the theory that they have their origin in the "sliding surface" of the Trades.[17] According to H. U. Sverdrup[18] the general variations in the features of this surface account for the various phenomena in certain parts of the tropics and their frequent appearance in other parts.

NORWEGIAN WEATHER SERVICE: FORECASTING BY BJERKNES THEORY.

The Norwegian Weather Service is directed from three forecast centers, Christiania, Tromso, and Bergen. Bergen ranks second to Christiania in population, and has really a more important forecast division—that along the western coast, divided into 30 districts, north to a certain point where Tromso district begins, fishing being the prin-

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[16] V. Bjerknes, On the Dynamics of the Circular Vortex with Applications to the Atmosphere and Atmospheric Vortex and Wave Motions. Christiania, 1921, *Geofysiske Publikationer*, Vol. II, No. 4, p. 83.

[17] This is referred to in the summary, Monthly Weather Review, March, 1921, of an article by C. E. P. Brooks and H. W. Braby as the "mobile center of action" under the clash of Trades in the Pacific.

[18] H. U. Sverdrup, Der Nordatlantische Passat, *Veröffentlichungen des Geophysikalischen Instituts der Universität Leipzig*, II, Ser., 1917.

cipal Norwegian industry, both winter and summer. Christiania forecasts for the few, yet very important, agricultural districts to the south.

Weather forecasting in Norway according to the Bjerknes methods dates from the summer of 1918, when the number of observing stations was increased from 8 to 90,[19] an essential step to the discovery and identity of the lines of convergence with full accuracy. The ideal situation being that a complete picture of the state of the atmosphere should be represented, even the increase of stations to 90 was but a modest approach to the requirement that distances between stations be suitable as space differentials under any conditions.

There are at least five types of forecasts sent from the centers of the Norwegian Weather Service. First, the forecast of general conditions sent to the various small districts, especially precipitation forecasts in summer for agricultural interests; in autumn the storm warning forecasts for the shipping and fishing interests. Each day the pilot of the passenger and mail aeroplane from Bergen, Haugesaud, and Stavanger receives information of present conditions along the route, including observation of wind, direction and force, from different heights, as obtained from pilot-balloon observations, and, in addition, short-range forecasts.

The fourth type are those sent to the newspapers of the important towns of the districts; these really come under the first type, for they are usually modifications of the same, containing also descriptions of the general weather conditions. Lastly, in winter, come the snowstorm warnings for the mountains along the Bergen-Christiania Railroad.

A weather chart is prepared three times daily, at 8 a. m., at 2 p. m., and at 7 p. m. Forecasting in general is carried on for the most part along the usual meteorological lines, using the principal meteorological elements, wind, precipitation, humidity, and temperature, forecasts for visibility being made in special cases.

The problem of forcasting naturally presents itself in two alternative forms. It can be dealt with in two ways, either the polar front waves in any stage of the cyclonic life cycle as well as other marked secondary discontinuities, or following the two air masses, polar and tropical. In tropical air high temperatures and hazy or foggy weather are to be expected according to the origin of the air masses and the tendency to the formation of drizzle or the slightest forms of precipitation. Even very slight showers of rain may occur under the circumstances described above. Brilliant weather may be expected where the polar front keeps far from the forecasting district, either far south in the tropical highs so that Norway lies in cold polar air, or to the north, far enough so that the station is farther south than the area of poor visibility. Often in southern Norway in the spring this is true, when the center of the so-called Azores high may be found in southern Ireland or even farther northeastward. High winds are rather rare in this case, although they may also be found in tropical air when a decided frontal wave sweeps the territory.

In polar air a different type of weather conditions is to be found according to the time that has elapsed since the air masses left the polar regions. If the forecasting district is swept by the nearly stationary northerly winds of a recent great cold outbreak, then the temperatures are naturally low and visibility is very good. The cloud forms are of the cumulus type and give rise to showers in places where the topography is favorable. Fog never occurs in this situation; killing frosts are not infrequent in summer time. The winds are generally gusty or squally, often reaching gale force, marking the advance of the cold polar air.

If some time has elapsed since the polar air left the northern regions the districts covered by it have, in general, an intensified anticyclonic type of weather, no precipitation but with morning or night fogs due to radiation. As a rule, the force of the wind is low. With such conditions in the north, this is the ideal situation for the formation of secondary fronts toward the south. The summer thundershower of central Europe is a manifestation of the condition.

In the situation mentioned above, local conditions influence weather to a great extent, especially the flat summer types, when the weather is wholly local. Eastern Norway and great parts of Sweden in summer are dotted with local centers of shower generation, when moist air has been carried in to them by the sea breezes or more general winds. These, according to J. Bjerknes and H. Solberg[20] are situated on the slopes of mountain blocks or free peaks, where the release of the latent energy of the moist air takes place most readily. The very puzzling formation of the local shower in the mountainous districts of Norway is organically connected with and explained by Bjerknes's theory. The forecasting work for the eastern part of Norway is mainly "shower forecasting," especially in summer. This involves in a high degree the study of the meteorological elements with regard to local and topographical conditions. One of the most important factors used in the forecasting of summer showers is absolute humidity.

If the polar front passes over the forecasting district, the weather type is cyclonic. This does not alone imply the sequence of the weather of a full-grown cyclone, as described in J. Bjerknes's first paper, but also the later remarkably different stages which occur in the life cycle.

Strong increases in temperature are naturally bound to occur with the advance of a well-developed warm sector. If the cyclonic wave is secluded, the warm sector at the surface of the earth may have very little contrast to the surrounding polar air masses. Frequently the secluded wave gives no rise of temperature in the bottom layers of the atmosphere, but rather often a well-marked fall, as the passage of the front marks an inflow of originally polar air.

Specific rain areas are set out along the polar front following the line, one preceding the warm front, one following at the rear of the cold. The first is broadest, reaching 200 to 400 kilometers, while the latter is very narrow, often no more than 10 kilometers. It is always kept in mind that when one is using rain areas to fix the position of the polar front orographical conditions play an important part in the formation and distribution of rain.

Precipitation in the typical cases of younger cyclones is first the warm-front rain followed by the narrower cold-front stripe after an interval. In a "seclusia" this is also the case, although the weather chart shows less distinction between the two phenomena. The "seclusia" has one rain area or in its last state of degeneration only a cloud area. The last wave of a series is the more stormy, due to the squally nature of the cold outbreak.

[19] Figure 1, page 120, V. Bjerknes, "Structure of the Atmosphere when Rain is Falling," *Quarterly Journal of the Royal Meteorological Society*, Volume XLVI, Number 194, April, 1920.

[20] Meteorological Conditions for the Formation of Rain: J. Bjerknes and H. Solberg. *Geophysical Publications*, Vol. III, No. 3, Geofysiske Kommission, Kristiania, 1921.

The visibility, according to the origin of the air masses, changes with the passage of the two fronts. It is in fact one of the main characteristics of the different air masses. In the case of a dying or a dead cyclone it may happen that the polar air in following the degenerated front has been polluted in its passage over England and northern France before reaching Norway. Fog often occurs either as radiation fog in the high-pressure wedges between the moving cyclones, or as wet fog in the warm sector, usually immediately after the passage of a well-marked warm front, the sliding surface of which cuts the earth or, less commonly, in the outer diffuse parts, for example, in the occluded part of a dying wave or along the tail of such a wave, the cloud shield cutting the earth's surface in both cases.

In addition to these general conditions Scandinavian forecasters are well aware of special conditions and take them into account in forecasting. The polar front may be halted by the mountain ridge between the western and eastern parts of southern Norway, or between Norway and Sweden in the northern part. The cloud masses may cross the summit of the mountain ranges and extend beyond as alto-stratus. The cross-section of the channel of warm air between the fronts is diminished by the pressure at the sliding surface and the wind forces consequently increase. The forecast "southerly gale with rain" is issued when a cyclonic wave advances to the western coast of Norway. The forced rise of air which takes place along the sliding surface of the warm front is considerably increased and veritable deluges of rain are sometimes experienced at Bergen in these situations. Naturally great amounts of precipitation occur when a raining front is retarded or becomes stationary. Orographical conditions may retard part of the front while the rest of it may continue. This may even lead to the regeneration of the cyclone on the flanks of the retarding mountain range. This is an especially frequent occurrence in winter in Scandinavia.

Cold fronts as well as warm fronts may be halted against the mountain ranges. When the winds blowing with a mountain wall to the right of them in the Northern Hemisphere the deflecting force of the earth's rotation causes an increased gradient there and the wind force is consequently increased. This is such an important phenomenon in Norway that it is often the cause of special warnings for storms.

The most frequent discontinuity is that between temperatures of stations lying on the two sides of the polar front. These differences in winter are usually very marked, the summer conditions, on the other hand, reducing them to a minimum, the discontinuity at the surface of the earth often entirely disappearing through conditions of radiation, cloudiness, precipitation, and different effects from the distribution of land and water. The movement of the line may often be followed only by changes of temperature at stations passed by the line.

In the vicinity of the low, the line of demarcation is usually followed by trough lines in the field of pressure. These can best be used when a close network of stations is used, for sometimes only the irregularities in wind motion indicate the presence of these trough lines. It may happen that both are missing when the movement of the front is very slow.

In all the reports received from stations for the forecast charts barometric tendencies are carefully transmitted, these being considered the best criteria for placing the line, three-hour changes being recorded. Before the steering line passes pressure drops rapidly, as the passage the fall is suddenly checked, the barograph trace becoming nearly horizontal. In front of the squall line there is usually a slight dip in the pressure record with a sudden rise at the passage of the line.

* * * * *

The ultimate ideal of the Bergen Weather Bureau is to issue detailed forecasts arrived at by mathematical calculations of the movements of the polar front. Most important is the velocity of propagation, and the prediction of position. In the computations due regard must be taken of local controls, acceleration, and retardation, which complicate the problem immensely. Such calculation of the probable movement of the front is part of the daily forecasting work, approximation fixing the amount of retardation due to orographical obstacles. This is determined in part by comparing the actual wind velocities and the velocities indicated by the gradient.

APPLICATION OF THE BJERKNES THEORY TO THE SYNOPTIC CHARTS OF THE UNITED STATES WEATHER BUREAU.

Probably the first instance of an application in United States of methods of forecasting as developed at the "Vaervarslingen paa Vestlandet" was the discussion by C. L. Meisinger [21] and his series of charts showing stream-lines giving the direction of the winds at the time of observation. He states, "This method has been devised by Bjerknes and used by him in his studies in forecasting in Norway and other parts of the world." Meisinger's charts also show the probable path of the wind of southerly component after it has left the ground at the wind-shift line. This article was one of a series in a study of the precipitation of sleet and the formation of glaze.

In partial explanation and to draw attention to the performance of the great cyclone of mid-February, 1919,[22] Meisinger made a second application of the Bjerknes theory and includes in his article eight remarkable illustions of the lines of the cyclone in question.

H. H. Clayton discusses an application of certain relations of wind to the gradient used while he was forecasting at Boston, Mass., from 1898 to 1903.[23] There may be thus a certain priority to Professor Bjerknes and Mr. Sandström, though Clayton's investigations were from a standpoint of practical forecasting without any attempt to discover the dynamic connections. His results were originally published in a short article in the MONTHLY WEATHER REVIEW, February, 1916, **44**: 80–81. Mr. Fox and Mr. Clayton seemed assured that if they could obtain telephonic reports of the time of beginning of rain in western and southern New England they could predict approximately the time of beginning in Boston. The plan was never put in operation, but Mr. Clayton states it needs only the energetic action of a sufficiently powerful organization to insure success.

Probably the first practical use in this country was that made by C. G. Andrus, observer, at Charleston, S. C., in September and October, 1920. At that time he applied Bjerknes' lines of convergence to the development of secondary lows on the ocassion of the International Balloon Races.[24] The main result of his work was an answer to the question, "Will a secondary unit of low pressure develop in the trough?" The conclusions reached were based on wind flow and temperature data. A squall-line, as long as it exhibits the well-known properties, may be considered a normal squall-line. Imme-

[21] Mo. WEATHER REV., February, 1920, 48 : 73–80 "Precipitation of sleet and formation of glaze in Eastern United States, January, 1920."
[22] Mo. WEATHER REV., October, 1920, 48 : 582–586.
[23] Mo. WEATHER REV., February, 1920, 48 : 83–84.
[24] Mo. WEATHER REV., January, 1921, 49 : 11–12. C. G. Andrus. "Application of Bjerknes's Lines to the Development of Secondary Lows.

diately a manifestation or tendency to manifest properties of the steering surface develops, the observer must be on the watch for the formation of a secondary. The first indications may be followed by a persisting tendency, and the secondary depression form, to remain, it may be, but a temporary one, yet the center of future developments. This seems to be a very frequent situation, not alone in the Mississippi Valley to which Andrus referred, but even more especially true of the Plateau Region to the southwest, as will be seen later.

A number of sporadic attempts to trace the lines on the Washington charts have been made at the Bergen Institute, but with only enough success to assure the investigators, that the lines were there and could be traced and used for more exact and detailed forecasting, especially with the introduction of more detailed reports.

In the preliminary investigations on the extension of the line of discontinuity about the pole, the charts published by the Deutche Seewarte under the direction of Captain Hoffmeyer,[25] have been more successfully used in determining the position of the line on the American continent and over the northern Atlantic.

More intensive work on the Washington maps (the details to be outlined later in this report) has shown the placing of the lines to be more or less satisfactory. Diversity of topography from west to east complicates the problem enormously but not nearly as much as the inadequate data given on the charts. In the first place, with the single exception of the Washington, D. C., reports, barometer readings are given to the nearest even hundredth inch and pressure variation for the nearest even hundredth, for a 12-hour period, abnormal change. Likewise, the same is true for temperature, even Fahrenheit degree, with even degrees for the 24-hour change. These conditions practically exclude an exact determination of the position of the steering surface, or warm front. The position of squall-lines or cold fronts seems more easily determined.

Only the barest possible data for clouds is available on the charts,[26] that is the reports of clear, partly cloudy, and cloudy, excluding the very best criteria available to the forecaster in the Scandinavian countries, the rate, direction, etc., of the cirrus sheet and other important details concerning the cloud cover. There are no visibility reports available, while in Norway fog, haze, and visibility are all reported. Time of beginning and time of cessation of rain are so important in marking the advance of either warm or cold fronts that they likewise have a place in the code reports.

Professor Bjerknes in his article[27] on the improvement of weather forecasting referring especially to the United States, suggests as of first importance the change from 8 to 16, or even 32, directions of wind. To observe and report these directions accurately "will be an important step in making it possible to draw the true lines of flow." This suggested change is not as important as an increase in the number of stations. In 1918, in Norway, when the increase of stations from 8 to 90 took place it gave an ideal distribution of about 80 stations to an area 5° square, from 58° to 63° north latitude, from 5° to 10° east longitude. The 8 stations at the beginning was about the distribution now to be found, for example, in 75°–70° west longitude, 40°–45° north latitude, or the following 8 or 10 stations, Portland, Me., Nantucket, Block Island, Hartford, New York, Concord, Northfield, possibly Canton and Philadelphia. That distribution is typical for the eastern part of the United States and is immensely better than any representative western section, say the possible three stations in the same latitudes, between 120° and 125° west longitude, Eureka, Red Bluff, and Roseburg. If the average were 8 to a 5°-area, this would be a great stride toward the ideal network. Professor Bjerknes suggests the change from climatological stations to telegraphic,[28] and then the number would be in about the same proportion to area as is used in western Norway. This is an ultimate ideal and probably the increase and improvement in radio telegraphy will some day make it possible.

With these generalized reports the criteria for indentifying the polar front were modified to fit the situation, in the study of the charts for January, 1921, which were chosen as an illustration for the United States.

The weather chart for Jan. 1, 1921 (Chart A.L.B.I.)—The warm front can be traced from the center of the cyclone in a general NW.–SE. direction first by the area of converging winds and secondly, by the actual discontinuities in temperature. For example, on the 8 a. m. chart of January 1, the edge of the steering surface of the cyclone central over Lake Superior, roughly marked by converging winds, has an average rise of temperature from stations east of the line to those on the west in the warm sector of about 12°. The line lies between Parry Sound and Saugeen, marked by the converging winds, between Oswego and Buffalo, where the temperature difference is 14°, Pittsburgh and Harrisburg, with a difference of 16° and continuing in a south-southeasterly direction, probably joining the cold front of the low off the Grand Banks.

These same stations are marked by discontinuities in the 24-hour barometer change; Harrisburg has had an abnormal rise of 0.04 inch over the 24-hour period, while the fall at Pittsburgh amounted to 0.18. A general cloudiness is to be found in the vicinity of the line, with precipitation at the time of observation at Parry Sound, Sault Ste. Marie, and Saugeen; at Houghton, Marquette, and Escanaba, where the line has passed, the amounts of precipitation have been respectively 0.01 inch and 0.08 inch within the preceding 24-hour period.

Summarizing, then the criteria for the location of the warm front are as follows:

1. General area of wind convergence toward center of the low. Increase in velocities.
2. Temperature discontinuities with greatest rise in 24 hours at the rear of the line, showing the warm front has passed.
3. Most marked fall of barometer for abnormal 24-hour change, with the passage of the line.
4. Precipitation along the line with general area of cloudiness, together with accumulated amounts for the past 24 hours.

One must take all these factors into consideration along with topographical conditions, which latter can not be enumerated here in detail but will be apparent to a more experienced forecaster.

At the rear of the warm sector comes the squall line running from the cyclonic center south or southwest. Often there is but one squall-line which marks the position of the polar front, far more frequently, several will be found marking the southward extensions of cold air of the advancing cold front.

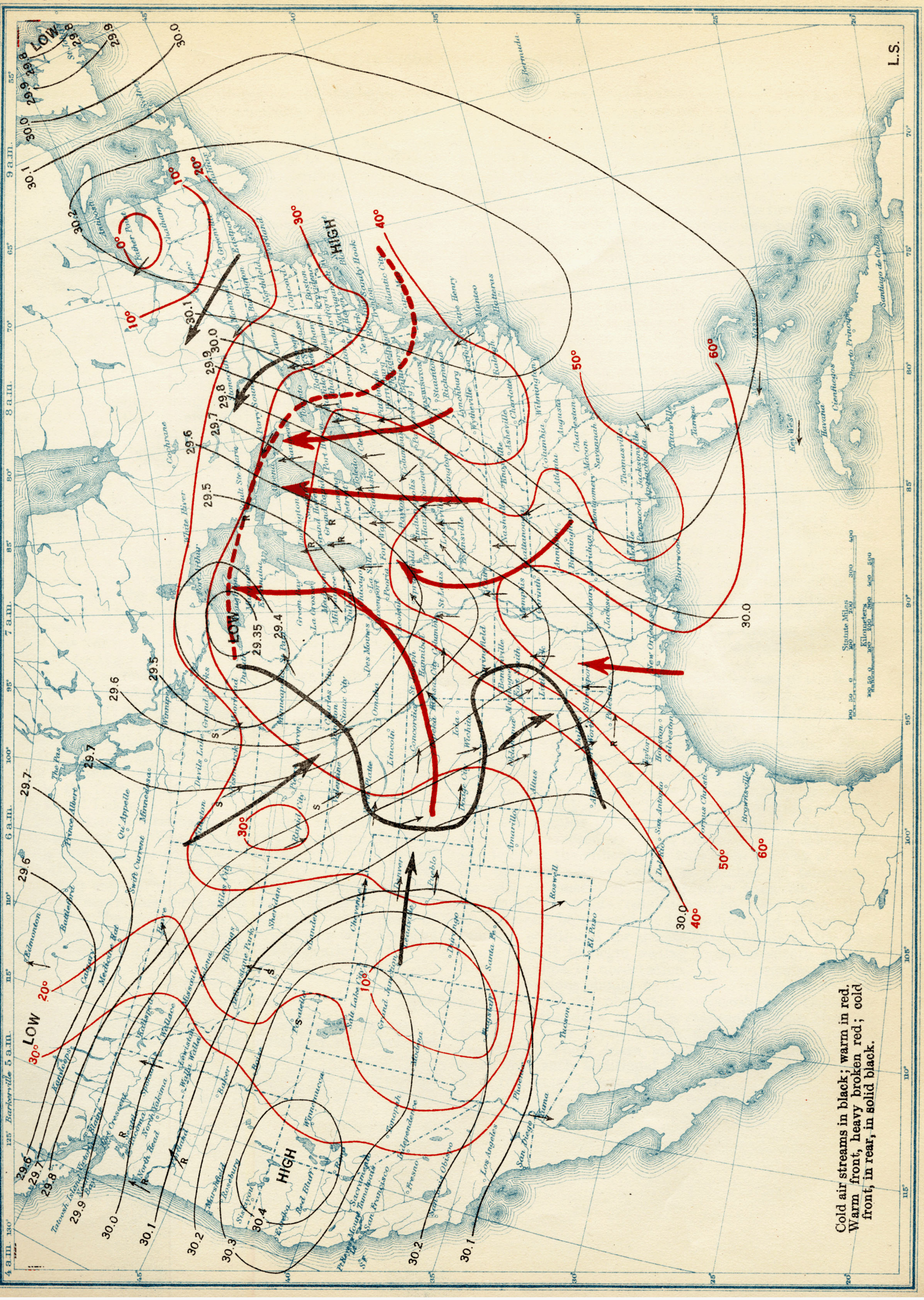
[25] V. Bjerknes: "Om Vaer-og Stormvarslinger og Veien til at forbedre dem." Figures 6–11, pages 6 and 7. (An address delivered by Prof. Bjerknes before the Trades Council, May 4, 1920, Bergen.)

[26] The manuscript cloud chart prepared in the Weather Bureau Forecast Division, contains many details not shown on the printed daily weather map—Ed.

[27] V. Bjerknes: "Possible Improvements in Weather Forecasting." Monthly Weather Review, February, 1919, p. 99.

[28] This would involve about 4,500 stations.

A. L. B. Chart I. Weather Map, 8 a. m., January 1, 1921.



Cold air streams in black; warm in red. Warm front, heavy broken red; cold front, in rear, in solid black.

The position of the squall-line can be determined by the following criteria, the demonstration of which is given later:

1. Slight convergence of winds, which in the case of Washington charts is often obliterated by the use of only eight wind directions. Increased velocities.
2. Temperature discontinuities, with more marked fall at the stations where the line has passed.
3. Rising barometer with the passage of the line, determined from the 24-hour abnormal change.
4. Precipitation and cloudiness with the passage of the line, followed by clearing weather.

A common phenomenon with the passage of the squall surface in the warm season is the thundershower. This is not the local thunderstorm due to intense heating, but a typical cold-front phenomenon.

The low-pressure area mentioned above had not one but a fan of squall-lines, one line lying well along the eastern edge of the Mississippi Valley marked by strong wind convergence, strong temperature, and pressure discontinuities, the difference in temperature between Shreveport and Dallas being 22°, Little Rock and Fort Smith 20°, St. Louis and Columbia, Mo., 12°. The pressure increases rapidly in a series of steps to the north, as shown by the chart, and three at least, possibly five portions, of squall-lines can be identified; for example, that between Valentine and North Platte, the temperature difference being 4°, the fall 16° at Valentine compared with 6° at North Platte, the wind west at the latter station with the weather clear, while the former has a northwest wind accompanied by snow, the precipitation for the 24-hour period is already 0.02 inch.

These LOWS, together with a third central in British Columbia, are the last of a series begun in December. The one central over Lake Superior on the second has moved to the northeast to the south shore of Hudson Bay. The secondary squall lines are becoming very complicated, at least five secondaries appearing, one over the northern part of Texas being a well-developed LOW. By the third this secondary is giving heavy rain in the lower Mississippi Valley.

The map on the 4th at 8 a. m. is very complicated. The secondary mentioned has swept off to the Atlantic, while the LOW from the Pacific coast now lies north of the Great Lakes.

This series is terminated by an area of high pressure growing over the Winnepeg district, its cooling temperatures extending far south, so that the polar front lies off the Atlantic coast, south in or below the Gulf of Mexico, and then the warm front of the first of the new series carries it nearly due north along the borders of the Plateau district to the center of the low, which for purposes of discussion we will call B, the A series being considered as closed by the cold outbreak under observation.[28] * * *

DISCUSSION.

By ALFRED J. HENRY.

Chart A. L. B. I is the Daily Weather Map for January 1, 1921, redrawn from the map submitted by Miss Beck and altered very slightly as to the position of the polar front in the rear of the cyclone center. In redrawing the map I have used only wind directions for those stations at which the velocity was at least 10 miles per hour (4.5 m. p. s.). This was done in order to eliminate from consideration the records for stations at which light winds or calms prevailed.

The result of this omission is, first, the lines of flow as indicated by the long heavy arrows are based upon a smaller number of actual observations, and second, some directions that did not conform to the general lines of flow, probably due to light winds or calms have been eliminated from consideration.

That part of the polar front line figured by the heavy broken line in red is precisely as drawn by Miss Beck from a consideration of all the data, but the polar front in the rear of the cyclone center makes a sharp westward bend over Nebraska and an equally sharp return to the eastward over southern Kansas and Missouri. In thus drawing the line a number of northwest winds in the upper Mississippi Valley were ignored, since it seems probable that the shift of the wind to that direction must have occurred very close to the moment of observation. The temperature at the stations so ignored showed very little fall from the readings 24 hours previous.

The eastward inflection of the line over southern Kansas is illustrative of the manner in which a wedge of cold air rather frequently penetrates into the warmer air in the southern segment of a cylcone. From the forecasters point of view such a condition if carried on in an extensive scale means the extinguishment of the cyclone, but if only to a small extent, as here illustrated, it simply makes for a diminution in the amount of cooling experienced in the rear of the cylcone, since the colder air is manifestly soon shut off from the original supply.

The paucity of data of wind velocities west of the Rocky Mountains is strikingly illustrated by the chart in question. The remainder of the maps for January, 1921, considered by Miss Beck, have not been reproduced for want of space, and for other reasons. Many of the maps were unsatisfactory for the reasons so clearly stated by Miss Beck on a previous page.

It may not be amiss to here consider very briefly the suggestions of Professor Bjerknes in a previous article[29] that the number of telegraphic stations in the United States be increased by about 4,500. A little calculation will uncover the difficulties which lie in the way of carrying out the suggestion. The number of telegraphic stations at present is slightly more than 200. Under the most favorable conditions the data from these stations can be charted in 35 minutes and, allowing 15 minutes additional for generalizing the data, the forecaster is able to begin issuing forecasts within an hour from the time of observation. If the number of telegraphic stations should be increased upward of twenty-fold it would be physically impossible to chart and generalize the data within a reasonable time after the observing hour, even if the present district forecast centers, of which there are 5, should utilize reports from only such additional stations as would lie within their respective geographic districts.

[28] The remainder of the article takes up in detail the discussion of the groups of cyclones that crossed the United States in January, 1921. Space does not permit the reproduction of the series of maps, but the originals have been filed in the Weather Bureau library and are available to students and others who may wish to consult them.—Ed.

[29] See footnote 27.